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Lewis Research Center
Cleveland, Ohio

Jennings Scholar Lecture presented at the Lewis Research Center, October 22, 1966

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION · WASHINGTON, D.C. · 1966

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It is, indeed, both a pleasure and a very real privilege to welcome this distinguished group of teachers, the Jennings Scholars, to the Lewis Research Center. You honor us in coming. Because it is to the young people of this nation that we entrust so much of the future, we applaud the concept of the Jennings Scholars and its recognition of the honored profession of teaching.

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I am particularly delighted that you will also have an opportunity to visit some of the installations of this Center this morning and see, at first hand, some of the work in progress. As one of a family of ten major centers of the NASA, we here at Lewis are responsible for research leading to better propulsion systems for both aircraft and space vehicles and for the power systems necessary to the generation of electric power in our future spacecraft. In addition to these research activities, we are also responsible for the development of the Atlas-Centaur launch vehicle and for the Agena family of vehicles which have successfully launched over 20 unmanned, scientific satellites and probes into space these last three years. Here at this Center, which is now entering its twenty-sixth year, nearly 5000 men and women are engaged in research on rocket engines, on electric propulsion, on solar, chemical, and nuclear power systems, in the search for better materials and fuels, and in the

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engineering and testing of launch vehicles. It is from such ground-based research and engineering that are obtained both the know-how for our current activities in space and the foundations for the more difficult and challenging tasks of the future. But rather than attempt to describe these activities by word or picture from this auditorium, I shall save that for your tour of the Center and devote my remarks at this time to some of the broader aspects of our nation's activities in space. And it has, indeed, been a broad, a varied, and a most-rapidly moving program.

Since our nation entered the space age - or, indeed, created this age - a short eight years ago, we have emerged from a period of exciting birth pangs, survived a lusty adolescence, and seem now to be entering a period of capable and reflective maturity. We have, in this very short span of time, reached the moon and planets, ringed our earth with communication and weather satellites, discovered more about the nature of our earth and its environment in space than in preceding decades of scientific exploration, and learned much about man's ability to live and work in space. We have, I believe, turned the corner towards the vision of President Kennedy when he said, five years ago, that "we sail a new ocean, the ocean of space" and called upon us to "take a leading role in space achievement, which in many ways may hold the key to our future on earth".

Among the most interesting and noteworthy achievements of this past year are those devoted to the field of lunar exploration, both as an expansion of our scientific knowledge and as a precursor to manned landings on the moon. (Figure 1) Standing alone and erect on the surface of the moon is Surveyor - its task completed, it remains in silent testimony to the ingenuity and curiosity of a culture which makes its home on another body of the solar system some 250,000 miles away. Launched from Cape Kennedy (Figure 2) on May 30th of this year by a new rocket burning liquid hydrogen for fuel, - The Atlas Centaur - this 2200 pound spacecraft, carrying more than 100 items of engineering instrumentation and a TV camera, was sent on its journey to the moon with outstanding accuracy. Upon arrival at the moon some 63 hours later, Surveyor was called upon to perform the complex task of landing softly and in the correct attitude - a launching in reverse, with no hands. Its first maneuver (Figure 3) changed its attitude from the cruise position to that required to align the thrust of its braking rocket along the flight path. When the radar on board the spacecraft measured an altitude of 60 miles, a 10,000 pound thrust rocket was fired to reduce the speed of the spacecraft from about 6000 miles per hour down to about 240 miles per hour. At the completion of this 40 second period of braking, the spent rocket case was thrown away, and the radar altimeter and a Doppler velocity sensor sent signals to an on-board computer and autopilot system. Based on these calculations, the thrust of three small vernier engines was adjusted to bring Surveyor down to the moon along a specified, predetermined flight path. Finally, at 13 feet above the surface, the vernier engines were shut off and Surveyor dropped gently to the surface of the moon at a speed of approximately seven miles per hour. The three landing legs contacted the lunar surface within ten milliseconds - that is, within one one-hundredth of a second - of each other and with the spacecraft mast standing within one degree of vertical.

It landed within nine miles of the aiming point established two days earlier and over 150,000 miles away, near the crater Flamsteed in Oceanus Procellarum - or, for the non-selenographers among us, about on the moon's equator and one-fourth of the way to the left of center as one views the full moon from the earth.

The immediate information obtained from this successful landing confirmed the findings of the earlier Soviet spacecraft, Luna IX - it did not sink in the layer of dust postulated by some scientists. A closer view of one of Surveyor's legs (Figure 4) revealed that the lunar material was disturbed and penetrated to a depth of only a couple of inches and is made up of a granular soil-like material of some cohesion. The manner of deformation is similar to what might be exhibited by a terrestrial, damp, fine-grained soil. Analysis of the bearing strength of this material indicates that it is capable of supporting a static, compressive load of about five pounds per square inch - enough for an astronaut in a pressure suit to walk about on without difficulty. A comparison of the predicted temperatures of the surfaces of the spacecraft with those actually measured indicates that it is not covered by dust.

The terrain within a mile or two of the landing site (Figure 5) is a gently rolling surface studded with craters that vary in size from a few inches to several hundreds of feet across. The area is littered with fragmental debris as large as three or four feet across. Analyses of the size, structure, position and reflectivity of some of these blocks of lunar material suggest that they are strong, single rocks of substantial cohesion and shear strength, different from the general finer-grained matrix of the lunar surface material. Looking towards the horizon (Figure 6) we find again a dark, relatively level, bare surface, with a few hills and low mountains standing against the darker sky.

The information obtained from our first Surveyor spacecraft has gone far to establish the technology and the feasibility of a successful landing of a manned craft, thus providing an important step towards the success of the Apollo project. But Surveyor, like its predecessor Ranger, provides information at only a single location on the surface of the moon. For wide-scale lunar mapping, and to provide data essential to a selection of a landing site for the Apollo astronauts, photographic coverage of a much larger area of the moon is required. Surveyor and Ranger have, therefore, been joined by Orbiter - an 800-pound spacecraft (Figure 7) which was placed in orbit about the moon this summer. Carrying two high-grade cameras designed for wide-scale aerial photography (if that is the right word), Orbiter can sweep an area up to 50 miles wide and 150 miles long on each pass. Orbiting about the moon once every $3\frac{1}{2}$ hours, the rotation of the moon about its axis brings a new scene into view on each orbit.

Unlike Surveyor and Ranger, Orbiter places its pictures on high-grade film instead of sending a 600-line TV picture back to earth. This exposed film is then developed and processed on board the spacecraft in a miniature film processing laboratory. A tiny spot of light - less than one twentieth the diameter of a human hair - scans the developed picture by tracing a path of 17,000 lines across each strip of film. The transparency of the film to the spot of light is then converted into an electronic signal which is sent back to earth for reconstruction of the picture for us to see.

The rather rugged and varied nature of much of the lunar surface is apparent in Figure 8. The crater evident in the upper right hand portion of the figure is approximately ten miles across, with the rim rising some 1000 feet above the adjacent surface. The sun, at the time of this picture, is about 12 degrees above the horizon. The photograph presented in Figure 9 has aroused rather special interest, primarily because it is of the back side of the moon. Now, I can conceive of no reason why the back of the moon should be any different from its front, but I suppose our special interest simply reveals our innate curiosity to make sure, to see what has never been seen before. The darker area in the left side of the picture is the Sea of Moscow, a mare of some 100 miles across, which was sufficiently visible in the earlier Soviet pictures to permit them to give it its name. Rising to the east, a few degrees above the horizon, we see the bright crescent of a new earth. More of that later.

Although our knowledge of the moon is now infinitely greater than it was just a year or two ago, each piece of information, each question answered, raises new questions. What is the nature of the moon below the surface, is there truth to the speculation of volcanic activity, does water exist below the surface and can life-giving oxygen be wrung from the rocks, - does, indeed, some form of life exist on the moon? While the possibilities of life on the moon, even in very primitive molecule-building forms, are quite remote, questions concerning the possibility of extra-terrestrial life are among the most profound that we can ask. And so we look eagerly about ourselves to find a likely spot and focus our attention on our neighbors of the solar system, Venus and Mars. Though Mars has been populated, irrigated, and civilized in fiction throughout the centuries, it remains for us, in our time, to really find out.

A first step in our exploration of Mars was accomplished last summer with the voyage of the spacecraft Mariner. With Mars orbiting about the sun at an average distance of 60 million miles from the earth, this spacecraft (Figure 10) had to be designed and qualified for a journey of nine months through space. To guide it on its long journey, it steered by the stars, - our first spacecraft to do so, - by finding and locking onto the star Canopus. Thin solar vanes, which were attached to the ends of the solar panels that generate the required electrical power, made use of the pressure of sunshine to aid in controlling its attitude in space.

The encounter with the planet Mars took place on July 14th of last year. During that day, the space environment near the planet was measured and 21 pictures were taken from a range of less than 10,000 miles above the Martian surface. These pictures were then stored on magnetic tape aboard the spacecraft for later play-back to earth. The entire picture taking sequence was completed in 26 minutes. All of these operations had to be conducted according to commands previously stored in the spacecraft rather than by "ground command" from here on earth because of a time delay of 12 minutes that was required for a signal to travel the distance of 130,000,000 miles that was then separating Earth and Mars. In fact, it was not until the next day, some 20 hours later, that we received an indication that pictures were, indeed, obtained. As Mariner continued its journey, it passed behind the planet as viewed from the earth, so that its radio messages were caused to pass through the Martian atmosphere. By measuring the change in strength and frequency and the bending of these signals as they passed through this atmosphere, we obtained our first accurate measurements of the density of the Martian atmosphere - essential information for subsequent landings on Mars.

Each of the 21 pictures stored in the spacecraft was then read back to earth by scanning the picture with 200 dots of light across a total of 200 lines. The shade of gray of each of these dots was further identified by a six digit binary code, thus permitting the reconstruction of a picture from the 240,000 pieces, or bits, of information. Picture transmission was limited by the power available to a rate of about eight bits per second. Some $8\frac{1}{2}$ hours time was, therefore, required to send one picture.

The first picture received amazed the watching group of scientists. Although the possibility of craters on Mars had been casually mentioned before this encounter, few were prepared for this moon-like scene (Figure 11). Although one wag was inspired to observe at the time that one word would be worth a thousand pictures, this one, Figure 11, was claimed by one of the scientists at the scene as being "one of the most remarkable scientific photographs of this age". Most prominent is a 75-mile diameter crater, with a three-mile crater in its eastern rim. Slopes range only up to ten degrees and no features sharp enough to cast shadows are observed. Crater rims rise to several hundred feet above the surrounding terrain, with the interiors depressed to thousands of feet. A number of craters near the evening terminator, that is, in the cool of the afternoon, appear frosted - a condition not inconsistent with the presence of water.

Although 21 such pictures don't go far in defining a whole planet, Mariner's view of Mars is a broad and profound one indeed when compared with all of our previous knowledge of this planet. If we can detect no evidence of life on Mars, we should not be disappointed. Similar pictures of the surface of the earth taken by our weather satellites also reveal no evidence of life here on our planet. Mariner IV has opened Mars as we might open a book at random, to glance at one page. To see more of this book of Mars, we plan to visit it again in 1969 and 1971 with follow-on Mariner spacecraft and in 1973 by Voyager - a much larger spacecraft which will send down a capsule to the Martian surface. This capsule may contain as much as 300 pounds of scientific instruments to dig and scrape on the Martian surface, analyze what it finds, and send its discoveries back to us on earth.

In addition to these explorations of our neighboring bodies in the solar system, we have, of course, also been learning much about the busy environment of space around the earth (Figure 12). The series of spacecraft called Explorers have measured the properties of the solar wind and its interaction with our magnetic field, have mapped the great radiation belts around the earth, and measured the great variety of particles, cosmic rays and energy fields in space. The Orbiting Solar Observatory, called OSO, has opened a new era in solar astronomy, measuring the ultraviolet and x-ray energy produced by the Sun - the center and driving force of all processes here on earth. The Orbiting Astronomical Observatory will carry a telescope above the earth's obscuring atmosphere to look at the heavens with new clarity and vision. OGO, the series of Orbiting Geophysical Observatories, have orbited the earth in both polar and equatorial orbits to survey the earth's magnetic fields and related phenomena in space. Other satellites have studied the ionosphere - the layer of ions and free electrons at the edge of our atmosphere so important to radio communications - and observed the effects of solar activity on our upper atmosphere. Indeed, not since the time that Galileo first looked at the moon with a telescope has such an opportunity for new knowledge presented itself to mankind.

In all of these initial explorations of the moon, the planets and the total space environment, it is clear that the use of these unmanned spacecraft is the simplest, quickest and safest way to do the job. It is equally clear, however, that later and more complex operations will require the presence of man's judgment and versatility on the scene. Here, you see, we are really exploring the unknown, and instruments can only be used to detect and measure what they have been designed in advance to do. If the conditions encountered are unexpected - and they usually are - they may well go by completely unnoticed by the instrument. It is in this phase of our explorations that the ability of a man to exercise judgment, to integrate many simultaneous events, to select the most interesting things to observe, to respond to the unexpected, will be of paramount importance. Further, it seems quite likely that for the long voyages of the future, the presence of a man on board the spacecraft will be necessary for repair, adjustment, or operation of the complex equipment. And beyond all these cogent arguments, it seems equally clear that man will participate in these explorations simply because he wants to. It is, perhaps, a measure of the nature and quality of man himself that he will not be satisfied until he has participated directly in these explorations and has gone to see for himself.

And so, a program of manned space flight has, as you know, been going forward in parallel with these unmanned explorations ever since our country entered the space age eight years ago. The programs are familiar to all of you - Mercury, which sent our first astronauts into orbit about the earth; Gemini, which provides flight durations of up to fourteen days for the crew of two men; and of Apollo, the program to send men to the surface of the moon and return them safely to earth. In spite of the concentration of effort and publicity that has been focused on this Apollo mission, it should not be viewed as an end-pointed program that will be completed when we reach the moon. It is, instead, only an intermediate step in our explorations between the Gemini program and the later development of permanent laboratories in space, lunar bases, and manned flights to the planets.

Throughout the Mercury and Gemini programs, most of the public's attention has been directed to the various operational aspects of the mission such as docking or rendezvous or to the design and operation of the launch vehicles and spacecraft. Let us, therefore, consider briefly some of the things we have learned, and some of the questions that remain, concerning the human component of these activities - of man himself in the space environment.

The seven flights of Project Mercury answered many questions that bothered us at the start of the program (Figure 13). We learned that man could easily withstand the accelerations of launch and reentry, could control the attitude of his spacecraft with ease, suffered no vertigo or disorientation even with loss of visual references, and could eat, drink, and urinate without difficulty if proper equipment for the weightless conditions was provided. Principal medical questions remaining at the completion of Project Mercury concerned the effects of flights of longer duration.

The activities of the past 18 months have been most eventful (Figure 14) and a great deal of progress has been made toward defining the physiologic cost of space flight and toward learning the operational requirements to support man in prolonged space flights. The Gemini program has now provided us with flight durations of up to 14 days, some experience with EVA, - i.e., extra vehicular activity - and has developed the techniques and equipment for rendezvous and docking with another object in space. In total, some 24 astronauts have logged over 1800 man-hours in space - nearly four times that of the Soviet cosmonauts.

Throughout the program, the excellent performance of all of the astronauts has demonstrated that the central nervous system of man functions very well under the rigors of space flights (Figure 15). Demanding performance such as the launch of Gemini VI, the rendezvous and the thruster problem in Gemini VIII, the EVA of Gemini IV, IX, and XI, and many accurate landings and recoveries at sea all demonstrate man's remarkable ability to handle stressful situations when properly trained and motivated. Normal sleep patterns appear present and visual acuity is unimpaired. Contrary to reports from Soviet experience, no abnormalities in the vestibular sense - that is, relating to the sense of balance from the inner ear - have been observed either during flight or in the post-flight period.

The first system in which a change was discovered due to space flight is the cardiovascular. This system has, therefore, been studied extensively by means of the electrocardiogram, the phonocardiogram, exercise tolerance, and the response of the circulatory system when the subject is rotated on the tilt table. By measuring the change in pulse rate and blood pressure of the astronaut when rotated from a horizontal to a near vertical position on this table, a quantitative measure of the condition of his cardiovascular system is obtained. Comparison of tests conducted prior to and immediately after the mission indicates the effects of the space flight. Some of these results are summarized in Figure 16. A progressive increase in pulse rate when rotated on the table is noted for flights of one, four and eight days, reaching a maximum change of 130 percent for the eight-day flight. However, for the 14 day flight of Gemini VII, the abnormal response disappears. Similar changes in total blood volume was also noted for these flights. I might also add, somewhat parenthetically, that all astronauts returned to essentially normal conditions in about two days after their return to earth.

Perhaps you have also heard something about the loss of bone calcium during the earlier Gemini flights. Indeed, (Figure 17) on the four and eight day flights, a loss of calcium of between 10 and 15 percent was noted.

This change also was reduced to negligible levels during the longer flight of Gemini VII. Clearly, the flight conditions of Gemini VII were more favorable to the human system than the earlier flights even if the astronauts of the early missions were unimpaired in the performance of their tasks and returned to normal at the completion of the flight. In spite of the very cramped quarters of this spacecraft, the astronauts of Gemini VII were provided somewhat greater exercise periods, pulling on a bungee cord, plus some isometric exercises. Some difficulty was also experienced in obtaining satisfactory sleep periods on the four and eight day missions. The firing of the thrusters, the nearly constant communications with earth, and the general duties of housekeeping interfered with the ability to sleep. When the astronauts attempted to sleep during alternate periods of work and rest, it was found that the spacecraft was so quiet that any activity by the working astronaut produced an aroused reaction in his resting companion. However, on Gemini VII, both astronauts were scheduled to retain their normal Cape Kennedy work-rest cycles, with both crewmen falling asleep during the midnight to 6:00 a.m. Cape Kennedy night time period. This process worked out very well. Both crewmen during this long mission also enjoyed a diet of some 2200 calories a day, in marked contrast to the 1000 calorie per day intake of the Gemini V crew. No irritability, excessive fatigue or impairment of performance were noted. during the entire 14 days of Gemini VII.

Summarizing the experience to date, significant changes due to space flight have been observed only with the cardiovascular, the musculoskeletal, and the blood-making systems and even these relatively minor or temporary effects have been brought under control by the provision of a proper environment in the spacecraft. The doctors are confident at this time in the ability of their astronauts to make the seven-day journey to the moon and back. But we should not be tempted to extrapolate these results to the longer voyages to the planets. It is a long reach from a flight of a few days to one of a year or more in duration to, say, Mars. We obviously have much work to do in earth-orbiting space laboratories before undertaking such ventures. The difficulties recently experienced during EVA - when the astronaut was outside the spacecraft with nothing to push against or anything solid to hang onto - also suggest that any future space station or a spaceship for one of the long trips to the planets should not be without some form of artificial gravity. Simply for convenience, if nothing else, a little gravity would be a great help. After all, we have evolved and learned all of our habits and procedures in a gravity environment. To pour liquid into a glass, to put something down on a table, to sweep the dirt into a corner are natural reactions which would be frustrated by an absence of gravity. And so, it seems to me that when we build our space stations or spaceships of the future, we will need to provide not only our earthly environment of an atmosphere, food, temperature and day-night cycles, but also take with us a little piece of gravity.

These programs - Surveyor, Mariner, Gemini, and many others - are but today's stepping stones to the moon and beyond. They find their origin in the decision of our nation to enter and lead in the exploration of space, legally expressed in the Space Act of 1958 and in the formation of NASA just eight years ago this month. It is pertinent to recall the opening words of that Act, which proclaimed that "it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind". It is, therefore, equally pertinent to inquire into the degree or manner in which our activities fulfill this requirement of "benefit to all mankind".

Of the eight national goals established by this Act of Congress, the first calls upon us to contribute to "the expansion of human knowledge of phenomena in the atmosphere and space". We proceed here on faith, but it is a strong faith that, in the long run, the search for knowledge and understanding about ourselves, the earth, the solar system, and the universe holds, in many ways, the key to our future well being here on earth.

But scientific knowledge does not consist of a mere collection of facts and laws nor does its value end with the formulation of unifying theories; theories which constitute, at bottom, a search for beauty and harmony in the world that is akin to our creativity in the arts, literature, or music. Such is the province of the student or practitioner of science. The value of these activities on a broad scale is that they make us more aware of the world in which we live. It has, in a word, bestowed comprehension. As we look upon the surface of Mars, or see our Earth (Figure 18), rising in splendor above the horizon of the moon, we have impressed anew upon our minds the immensity of the universe around us and the beauty of the planet that we all share. By so increasing our awareness - which appears to be the ultimate justification for any intellectual activity - we are introduced into new ways of thinking and new ways of looking at old questions.

The new knowledge to be attained in and from our activities in space cuts across practically all fields of science - chemistry, physics, geology, biology, astronomy, psychology, and just about any field you wish to name. Because of this universality of space as an arena for nearly all of science, the conduct of space exploration is providing a unity and a drawing together of many people of varied skills and backgrounds. The astronomer has a vital interest in the chemistry of planetary atmospheres, the frontiers of biology lie in the atomic structure of matter, and the designers of machines cannot ignore the psychology and physiology of humans. We are experiencing here, I believe, a move away from the narrow specialization in science that has existed for the past several centuries towards a return to the older traditions of natural philosophy. This move toward a broader spirit of inquiry into the physical surroundings of man is one of the important accompaniments of space research.

For our young people who may choose a career in the sciences, I, therefore, encourage the avoidance of a narrow specialization of study that may seem the easy road to competence. The chemist must know what's going on in biology, the designer of a future spacecraft cannot escape the sciences of electronics, chemistry, aerodynamics or biological sterilization. For a time, a narrow specialization has a certain survival value and can even lead to an early establishment of a scientific reputation. In the end, however, it usually leads to early obsolescence. Just as most of the scientific frontiers of today were unknown or little developed 10 or 15 years ago, so many of the fields in which today's young people will be working in the 1970's or 1980's are probably little known today. This rapid rate of change of knowledge in practically all fields further emphasizes the importance of what may be termed the method and art of the subject matter as opposed to mere content. The student of science, for example, needs not only a knowledge of the content of current scientific theories - which have a way of changing from time to time - but also an understanding of the method of science and an appreciation of why a scientist chooses to look at things the way he does. Engineering design involves, to be sure, a knowledge of the behavior of materials and current methods of stress analysis, but good design requires a facility in the art of the subject. The content and substance of the subject at hand may be obtained from the textbook and lessons by rote. The more important ingredients of structure, method, and form - the art - of the subject requires, however, a transfer of feeling and value from teacher to student. With this transfer accomplished, things of enduring value are secured and the subject matter becomes lively, interesting, and useful.

The construction and operation of a spacecraft also embodies things of both a transitory and an enduring nature. When we look upon Mariner, for example (Figure 19), we may marvel at its engineering sophistication or the pictures of Mars that it obtained, but we see only the top of an iceberg. Beneath the surface lies both a demand for perfection and an organization of human effort that is new to the world. Each of Mariner's 140,000 pieces and the 300,000 parts of the rocket that launched it into space had to work perfectly or all would have been lost. The thin line that separates success and failure demands of all of us a new level of perfection and excellence in all that we do. We have learned many stern lessons these past few years, and among them is the sure knowledge that a loose wire, a soiled part, or a nearly perfect design is the sure cause of failure. Attention to detail, soundness of design and test, and a constant awareness that a shortcut is the path to failure, are among the touchstones of successful space age engineering. In all that we do, in design, material handling, construction of parts, packaging, inspection, assembly and testing, we must accept the proposition that perfection is not only possible but necessary. To be satisfied only when we have done our very best, with the sure knowledge that any less will result in failure, is surely a hard lesson of the space age that can well be applied to many of our earthly activities.

The organization of human effort behind the flight of a Mariner, or any other spacecraft, is global in extent. Every launch from Cape Kennedy involves an array of agreements with people throughout the world. The construction of the spacecraft alone required the coordinated efforts of over 50,000 people spread throughout a scientific community of many universities, of hundreds of private contractors, and over a dozen separate elements of our national government. At our mission control centers come the voices of men and women throughout the world, each doing his part and each betraying by his voice his devotion to the job at hand. Many of their voices came from places bearing familiar names - Grand Bahama, Antigua and Hawaii, and many from places on this earth bearing new or strange sounding names - from Carnarvon, Tananarive, and Tidbinbilla. During the $8\frac{1}{2}$ hours that Mariner took to send us each of its pictures, the world turned a third of a revolution on its axis. Part of a picture would, therefore, be received in Spain, part in Australia, or part in our own country. Each piece became a meaningful whole through a global network of communication and cooperation. Truly, electronic artistry on a global scale.

As we contemplate the nature of tomorrow's world, it becomes clear that an essential element of our future will be world-wide communications through orbiting satellites. Just as the telegraph unified this country a century ago and the telephone has become essential to the conduct of almost all commercial and social activities within this country, so will the ready availability of world-wide communications be of great importance to our future role in the world. It is perhaps difficult for us to imagine the social isolation in which most of the human race still exists - and from which much of it is now clamoring to escape. Isolated tribes and villages, and parochial nationalistic groups are still the rule in much of the world. But now, in a brief moment of time, all this will end. The coming of the communications satellite will make it impossible for any human group to be more than a few milliseconds from any other. The social consequences of this - for good or evil - will surely be as great as were those of the printing press or the internal combustion engine.

As trade patterns assume global proportions and new industrialization is brought to many distant lands, the demand for overseas communications has rapidly grown. The number of overseas telephone calls has risen from two to eight million per year over the past ten years. A further increase to 40 million per year is projected for the decade ahead. And yet the capacity of our overseas telephone cables is exceeded almost as fast as they are laid. In 1956, we had a capacity for 36 telephone circuits between North America and Great Britain. This was subsequently expanded to a capacity of 300 voice channels by the addition of three more cables in 1964. Only now are we completing a globe-girdling cable having an 80 voice channel capacity. And yet we foresee the need for a fivefold increase in telephone messages in the next ten years, exclusive of any use for transmission of television pictures. A television picture may be roughly considered as requiring the same communications capacity as 600 channels of voice transmission, clearly beyond the capability of all of our overseas cables.

Because orbiting satellites can utilize microwave techniques - which travel only in straight lines in contrast to radio waves which reflect from the ionosphere - their communications capacity is truly prodigious. Following closely on the heels of Telstar and Relay, the experimental satellites, is Early Bird, the first of our commercially operated satellites (Figure 20). This satellite, though only an infant compared to what may be expected in the future, has a capacity for 240 two-way telephone circuits, a black and white television transmission in two directions at the same time, or color television in one direction. Little wonder that Frank Stanton, the president of the Columbia Broadcasting System has said of Early Bird that "the mountains have been leveled and the oceans dried up by an 85-pound piece of scientific jewelry transmitting a 6-watt signal".

The coverage provided is, of course, global in nature, (Figure 21) and hence can tie any country in the world to any other country without dependence upon linkage to a third country. It can span oceans or continents with equal ease and, once such a pattern of global satellites has been developed, the price of admission to a global communications capability is the cost of a terminal station.

Some of the television pictures we have already seen from abroad via Early Bird are dramatic examples of things to come (Figure 22). Equally thrilling as the safe recovery of our astronauts was the realization that here we were, in our office or home, seeing an event live, as it happened, from the middle of the Atlantic Ocean. Other significant transmissions include Pope Paul VI speaking from the Vatican, open heart surgery performed by Dr. DeBakey in a Houston hospital, or a colorful Mexican dance and a pavilion in Quebec. Figure 23 of a recent "Town Meeting of the World," linking statesmen from various parts of the world into a single forum via Early Bird, dramatizes the potential impact of space communications toward improved understanding among the peoples of the world. Here we see the American commentator Eric Sevareid engaged in discussions with Lord Chalfont of England, General Pierre Callois of France, Franz Josef Strauss of West Germany and Senator Robert Kennedy of our own country.

It is also noteworthy that this Early Bird satellite was bought and is operated by a private corporation created by the passage of the Communications Satellite Act of 1962. This unique corporation, imbued with a strong sense of public responsibility and subject to close government scrutiny and regulations, already has capital resources in excess of 200 million dollars. Stock is held by 164 communications carriers and more than 140,000 stockholders are distributed throughout the United States and abroad. The creation of this Communications Satellite Corporation, with its remarkable combination of public purpose and private enterprise may show how other great public purposes can be attained without adding to the structure of government.

Another area in which the use of orbiting satellites promises to be of great benefit is in the field of meteorology. The weather at any point on earth is, of course, a part of a truly global activity. And yet, prior to the advent of the weather satellite, we have been able to observe and study the operation of this global system from stations that provide coverage over only ten percent of the Earth's surface. It has been a little like asking a doctor to evaluate the state of health of a patient while being allowed to inspect only a randomly selected ten percent of his total body. But a single satellite in a polar orbit (Figure 24) can provide a complete survey of the entire earth on a daily basis. In the case of Nimbus, attitude control devices keep the cameras and other sensors pointed toward the earth; at the same time, the solar panels are rotated such that they are kept normal to the rays from the sun. When Nimbus enters the shadow of the earth, electric power is provided by storage batteries that are recharged on each orbit. Because the usual TV cameras cannot be used at night, photography of the earth during this part of the orbit is obtained by infrared techniques. By measuring the degree of warmth or cold of the object in view of these infrared sensors, a picture of the earth and its cloud cover is obtained that is fully equal to the daytime coverage by camera. As the earth rotates on its axis beneath the satellite, successive paths are swept by the cameras, thus providing the daily global coverage.

Two other features should be noted. First, in addition to simply carrying cameras or infrared sensors to see where the clouds are, these satellites also carry devices called radiometers and spectrometers that are designed to be sensitive to energy of various wave lengths. These several devices provide information on such features as water vapor concentrations, surface and cloud top temperatures, average stratospheric temperatures, total earth atmosphere thermal radiation and the earth albedo, or reflectivity. It is through putting all these, and other, factors together that an assessment of the total heat budget of the earth can be made - which is, in effect, the distribution and nature of the energy that makes and drives our weather - and upon which are based the expectations for accurate long range forecasts on a scientific, instead of simply an observational, basis.

In the satellite's normal mode of operation, these data are stored on magnetic tape and read out when passing over a central data receiving station. Nimbus, however, also carries an automatic picture transmission system which reads out a picture of what it is looking at every 208 seconds, without any command or interrogation from the ground. This picture can, therefore, be received by any station within signal range and equipped with the necessary antenna, receiver and facsimile machine - equipment valued at approximately $30,000. And so, we are essentially saying to the whole world "here is a picture of the weather within 2000 miles of you - if you want it, just tune in". Information conveyed in this manner is particularly useful in isolated areas where meteorological communications networks are scarce, unreliable, or non-existent. At the present time, some 150 of these stations are in operation, 44 of them in 26 foreign countries.

One example of these automatically-transmitted pictures is shown in Figure 25. Although the photographic quality obtained with this experimental equipment is not high, it is entirely adequate for meteorological analyses. Here we see hurricane Alma churning its way up the Florida coast this summer. The tip of the Florida peninsula is visible, and to the south lays the island of Cuba. By studying many such pictures, together with other pertinent data on temperatures, cloud heights, wind velocities, water content, etc., we are learning much about the development of storms and the factors that determine their future course and endurance.

By putting several such pictures together, we can, of course, obtain a view of the weather over a large area. One such mosaic covering the entire U. S. is shown in Figure 26. Of interest here are the rain-producing storms along the west coast, ice in Lake Erie, snow cover over the northeastern United States and clouds in the cold airflow off the east coast.

Although still in their infancy, and largely devoted to research or experimental purposes, our weather satellites have already been of significant operational benefit. Over 100 typhoons and 30 hurricanes have been observed and tracked in both the Pacific and Atlantic Oceans. Nearly 1000 improvements in weather map analyses have been effected and some 3000 special storm advisories have been issued, both nationally and internationally. Of particular interest to NASA, for example, was the decision to terminate the flight of Gemini V one orbit early because it was observed in one of the Tiros pictures that the planned recovery area was uncomfortably close to Hurricane Betsy.

When we link the capabilities of a satellite for continuous, rapid global coverage with the sensitivities of new types of sensors, many exciting new possibilities come to mind. Among these sensors are radar, infrared imagers, infrared radiometers and spectrometers, microwave radiometers, and magnetometers. With such instruments in orbit, which can measure the temperature, color, water content, shape, density, or reflectivity of what they look at, we can, for the first time, begin to assess many important resources of the Earth. Among these resources are mineral districts, soils, crops, timber, water, housing and transportation networks. And, as we begin to map and assess these important resources, we will begin to have in hand the information required for their proper control and management. The importance of better management of the resources of our shrinking Earth can hardly be overstated. Every day the population of the Earth increases by 80,000. The growth of world population - the consumers of these resources (Figure 27) - is expected to double before this century is over. It is also of greatest significance that most of this increase in the world population will occur in the emerging lands of Africa, India and Asia. If all of these people are to be adequately clothed and fed and provided with the products of industry that they are demanding - and if their demands are not to shake the world - new sources of food, energy, timber, minerals, and fresh water must be found and controlled.

Although the elements and tangible benefits of this program - An Earth Resources Program - are still highly spectulative, they are of equally great potential. Included among the studies currently under way to learn how to use this new capability relate to soil and crop control, the identification of new lands to bring under cultivation, the detection of forest and crop disease, and locating sites for new reservoirs. We will soon need a world water map to find and identify the extent of this important resource in the soil, in the snow and ice fields, and in the atmosphere. As we manipulate our environment, we will also need to watch the movement and expenditure of this essential resource - all of which may be possible from a satellite. Measurements of the temperatures, depth, and currents of the oceans are important to fishing. Frequent coverage of the ocean areas on a global scale can lead to identification of new fishing areas, the location and tracking of schools of fish and marine mammals, and following the "red tide". Coastal mapping may be of importance to the petroleum industry as well as to shipping and fishing. Early detection of forest fires may save much of this resource which has, in the past, been lost when they occur in remote areas and go undiscovered until too late - such as the five million acres of Alaskan timber that were destroyed in this manner in 1957. The use of satellites has even been suggested as a valuable aid to laying out transportation networks and in urban planning.

These possibilities are by no means either definite or exhaustive. Some of the pictures we have already obtained with simple cameras and infrared sensors - instead of with the more sophisticated devices mentioned earlier - are, however, suggestive. For example, in the photograph of

Figure 28 of the Great Bahama Banks, we can see the detail of the ocean bottom, the location of shoals and reefs, the variation in the depth of the water and some idea of the currents. The silting of the mouth of the Colorado River, and its consequent influence on all shoreline and water-related activities in this area, are apparent in Figure 29. The use of an infrared sensor to survey timberland such as illustrated in Figure 30, enables us to readily detect the presence of insect damage. As noted, the damaged trees appear blue while the healthy trees show up as red or pink. To the eye, of course, they all appear green.

These, then, are some of the glittering possibilities of our future in space, as well as some of the results of our current activities. Taken altogether, this program represents a national response to a challenge to our technical leadership, the public acceptance of difficult goals to be pursued in an open manner for all to see, to share, and to thus become participants, the expansion of our knowledge of our environment, the development of technical capabilities of importance to the future society of mankind, and a chance to tangibly demonstrate our innermost desires to share our wealth with the people of less fortunate or more modestly endowed nations. It represents an activity that is presently absorbing the energies and attention of more than 400,000 skilled people in the laboratories, workshops and factories throughout our nation. Our activities in space, and the many sciences and technologies to which they give birth, will surely have a large impact on the future life of all of the world's peoples.

But all of this is but a part, one element, of its total potential. We stand today with capabilities undreamed of a 1000 years ago and unforeseen a 100 years ago. These are capabilities - and we need them - but they are capabilities in human hands and they must serve human purposes. The glittering promise and the awesome problems of the future come hand-in-hand and to deal with both will require men and women who are both highly trained and well educated. Science, and its products, and its power, have now entered the mainstream of our lives and it is important that the practitioner of this art be not only skilled in his trade but also familiar with the literature, history, arts, and the political and social heritage that form our civilization. Similarily, for the many other non-technical professions, a general background in the sciences and what it is doing is of importance because of both its intimate involvement in our daily lives, and as part of the cultural heritage of every educated person. It is essential that we have the wit and knowledge to constantly back away from our technology and be able to realize that this technology is building a society for human beings and that it is the kind of people we have that is, in the end, going to determine the use of this power.

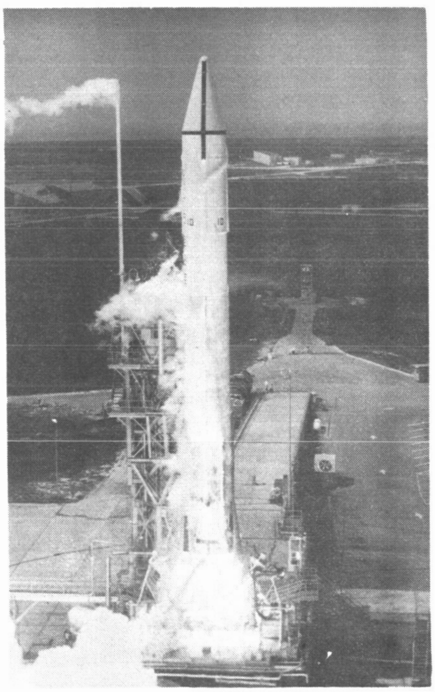
As we move ahead, as I am sure we will, and continue to pursue the values that science can offer - the elimination of starvation in the world, the curing of disease, the convenience of faster travel and ready communications, the development of new sources of energy, the control of the resources of the earth, - as we pursue these goals, we must make certain that we do so with a sure and steady eye on the older values of individual freedom and the dignity of man. The great task ahead, therefore, is to be able to utilize our rapidly growing science and technology and its ever more complex social structure not only to lift the burden from the backs and minds of men but also to find, within this structure, a path to a peaceful world and new expressions of man's worth as a spiritual entity possessing creative powers.

And this, at bottom, is the great task of education. We honor you, therefore, for your accomplishments as teachers and respect you for the importance of the task you have undertaken. To meet this task of the future, we place our faith in our young people - to the youth of your classrooms and to thousands of others like them throughout our land. They hold, and they have, our faith that they will master the machines, will sit in wisdom at the council tables of the world, and will use the new sciences and technologies for the betterment of all mankind.

E-3732

CS-41399

Figure 1. Surveyor looks at its shadow.



CS-39840

Figure 2. "Lift off!" Atlas-Centaur starts Surveyor on its journey to the Moon.

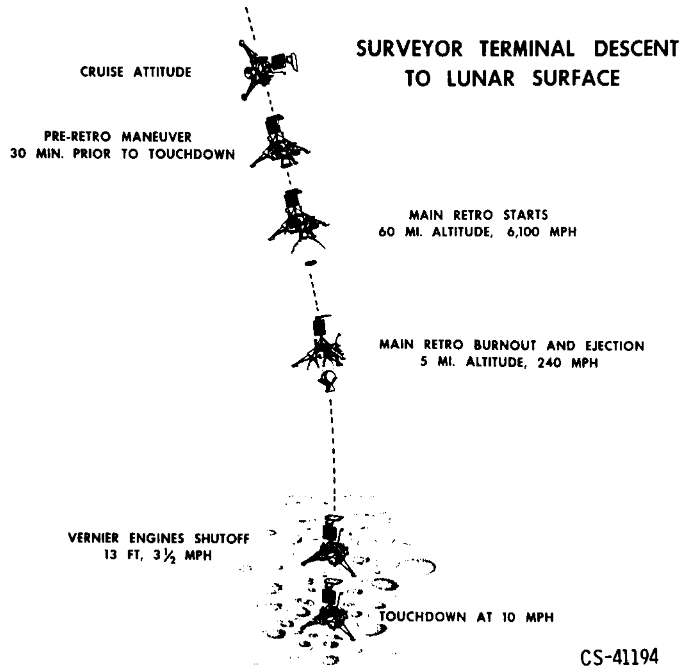


Figure 3. Terminal descent sequence of Surveyor.

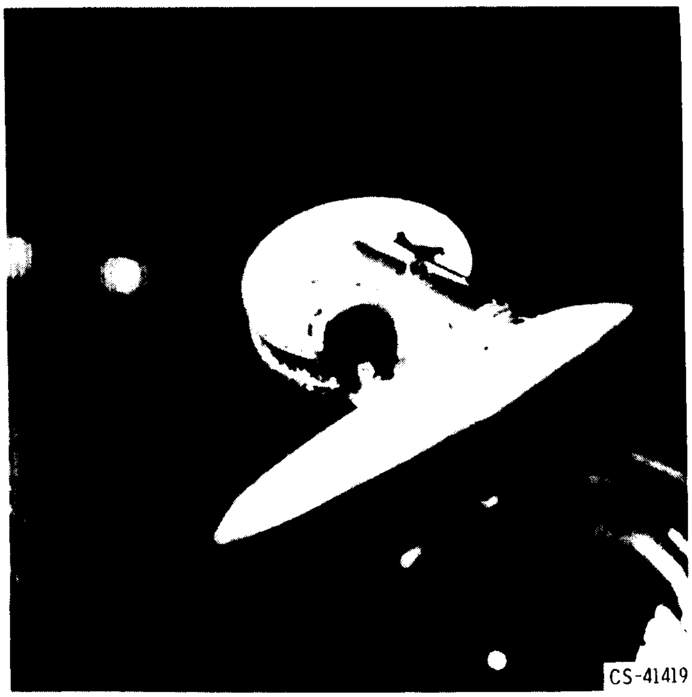


Figure 4. Surveyor makes a footprint on the Moon.

E-3732

E-3732

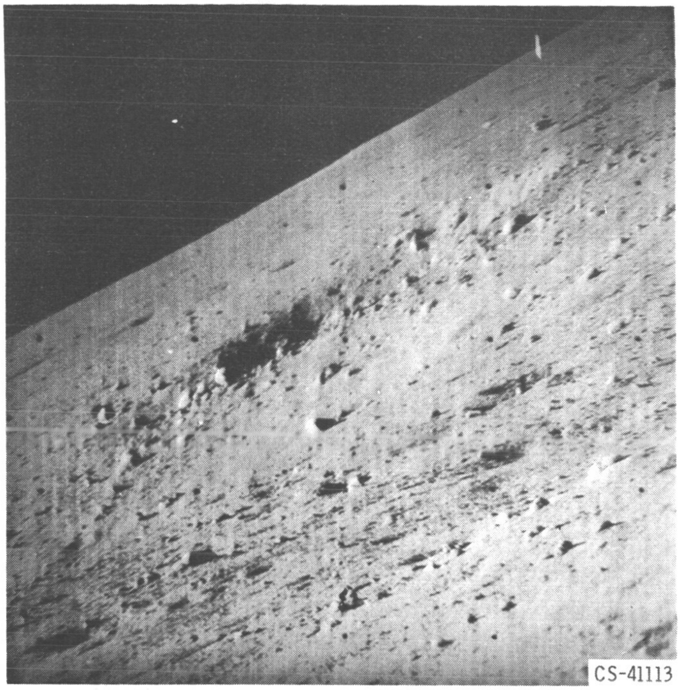


Figure 5. "A gently rolling surface littered with fragmental debris and studded with craters."

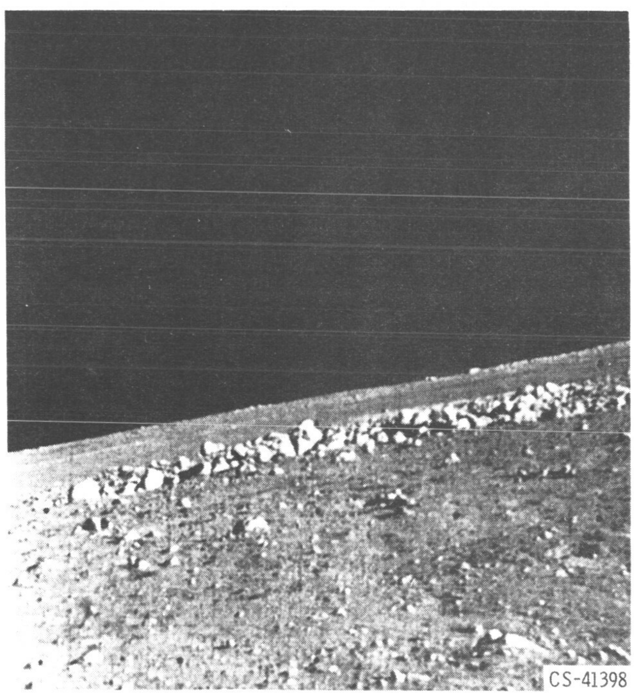


Figure 6. Looking towards the horizon of the Moon.

Figure 7. The Lunar Orbiter spacecraft.

Figure 8. A view of the moon from Orbiter.

E-3732

E-3732

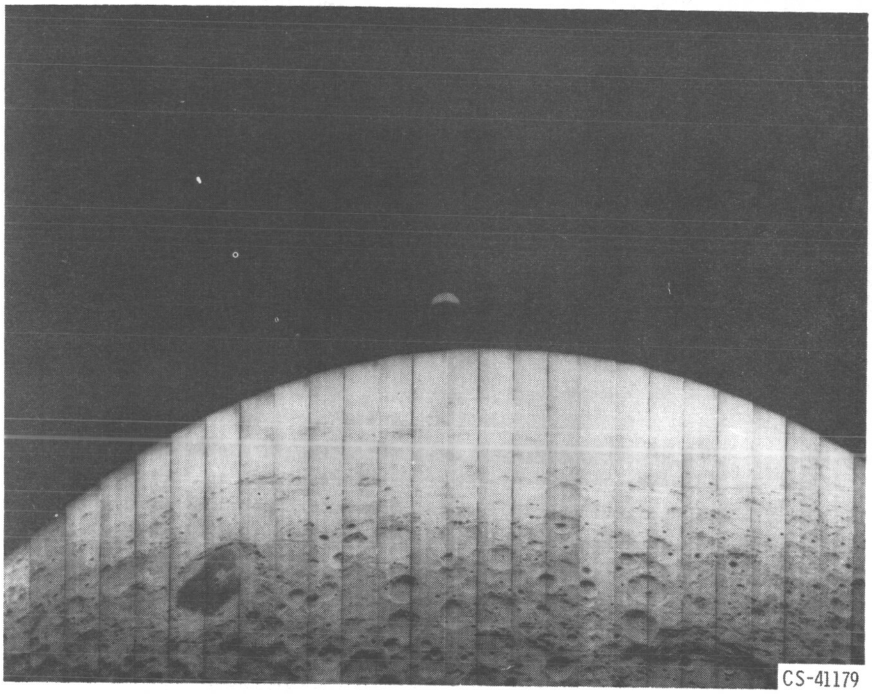


Figure 9. The bright crescent of a new Earth rising over the "back side" of the Moon.

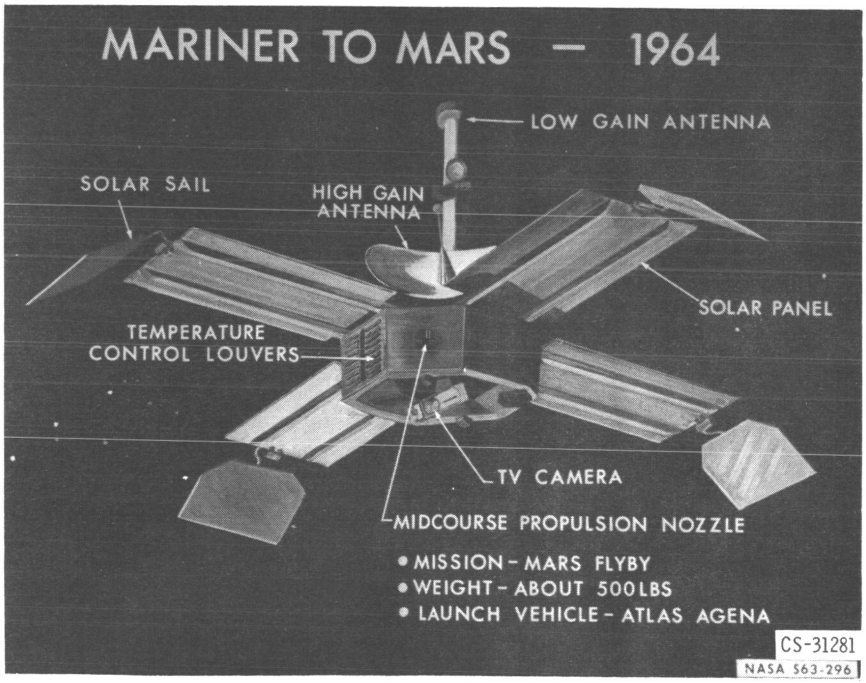


Figure 10. The Mariner-Mars spacecraft.

E-3732

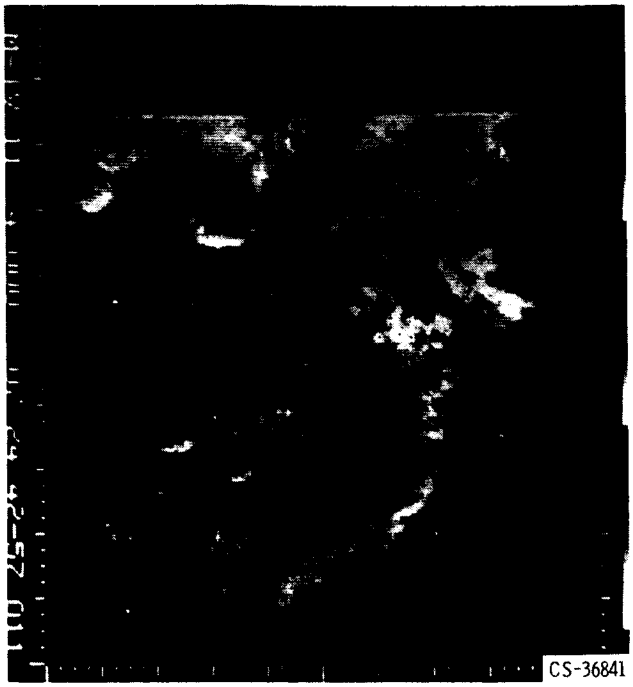


Figure 11. The surface of Mars from 9,000 miles.

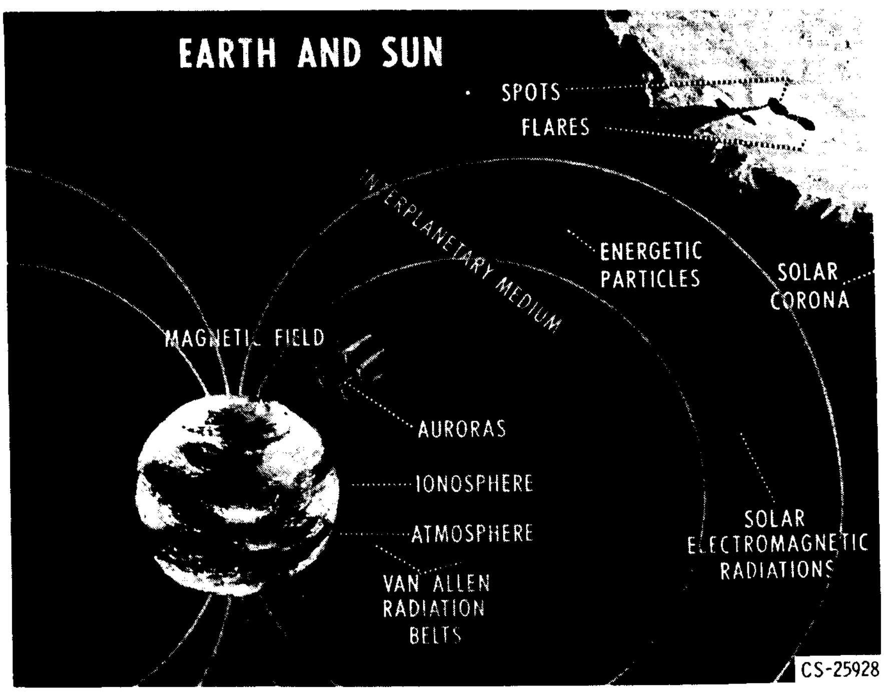
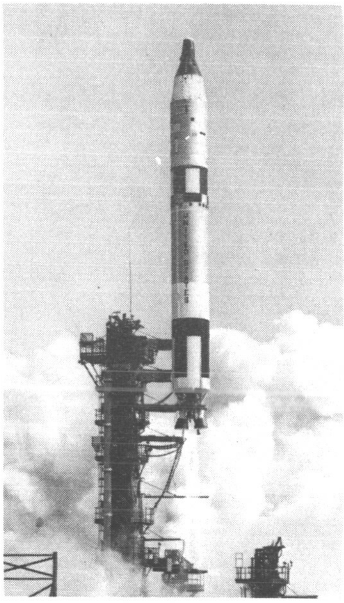


Figure 12. The space environment.

E-3732



NO PROBLEM

LAUNCH AND REENTRY ACCELERATION

SPACECRAFT CONTROL

PSYCHOMOTOR PERFORMANCE

EATING AND DRINKING

ORIENTATION

URINATION

REMAINING PROBLEMS

DEFECATION

SLEEP

ORTHOSTATIC HYPOTENSION

CS-41200

Figure 13. Post Mercury medical status.

GEMINI MANNED FLIGHTS

FLIGHT	CREW	LAUNCH	DESCRIPTION	DURATION		
				DAYS	HRS	MIN
PROJECT GEMINI						
G-III	GRISSOM YOUNG	3-23-65	3RD REV MANNED TEST		4	52
G-IV	McDIVITT WHITE	6-3-65	1ST EXT DURATION AND EVA	4		56
G-V	COOPER CONRAD	8-21-65	1ST MEDIUM DURATION FLT	7	22	56
G-VII	BORMAN LOVELL	12-4-65	1ST LONG DURATION FLT	13	18	35
G-VI	SCHIRRA STAFFORD	12-15-65	1ST RENDEZVOUS FLT	1	1	53
G-VIII	ARMSTRONG SCOTT	3-16-66	1ST RENDEZVOUS AND DOCKING FLT		10	41
G-IXA	STAFFORD CERNAN	6-3-66	2ND RENDEZVOUS AND DOCKING 1ST EXTENDED EVA	3	1	04
G-X	YOUNG COLLINS	7-18-66	1ST DUAL RENDEZVOUS (WITH GTU10 THEN GTU8)	2	22	47
G-XI	GORDAN CONRAD	9-12-66	RENDEZVOUS AND DOCKING ON 1ST ORBIT	2	23	17
			TOTAL DURATION	36	11	01

CS-41117

Figure 14. A summary of Gemini flights as of October 1966.

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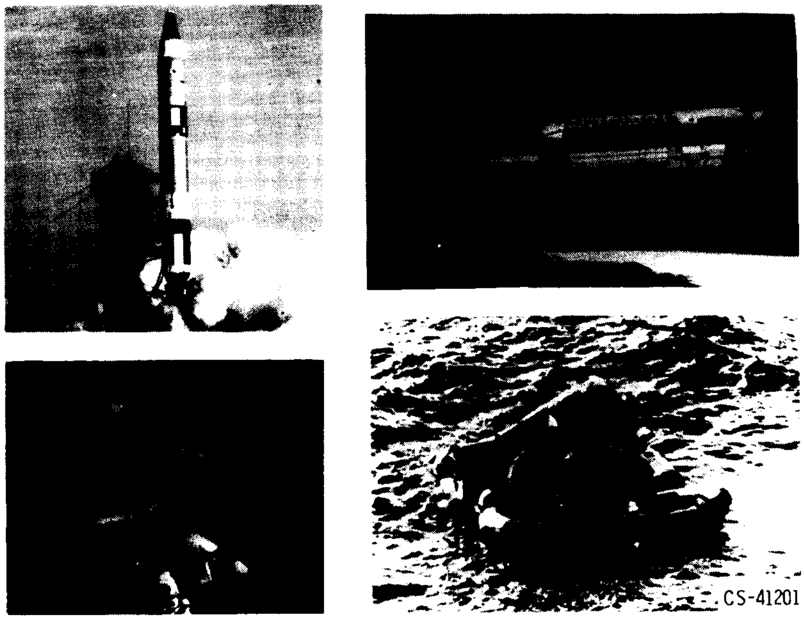


Figure 15. Evidence of normal central nervous system function.

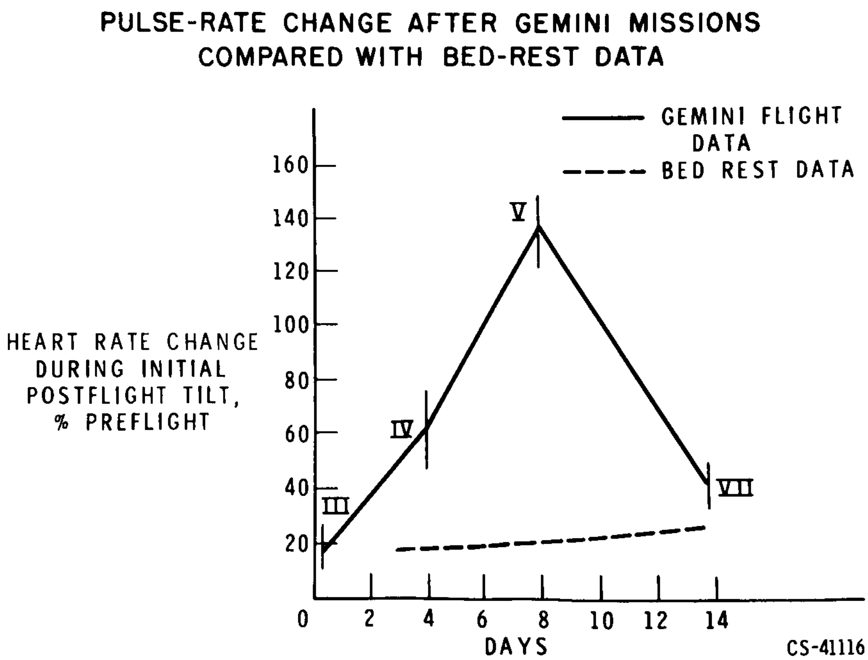


Figure 16. Pulse-rate change after Gemini missions.

E-3732

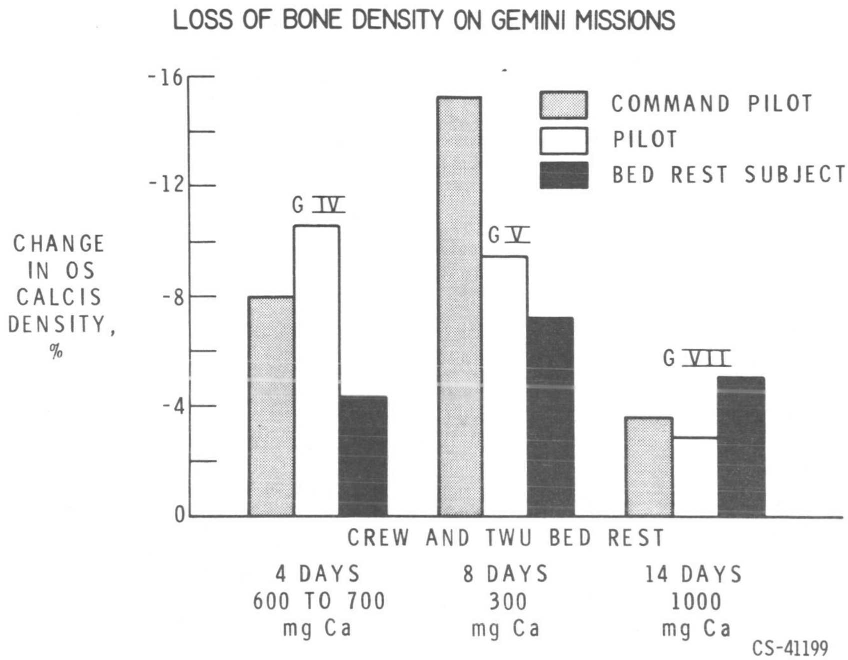


Figure 17. Calcium loss after Gemini mission.

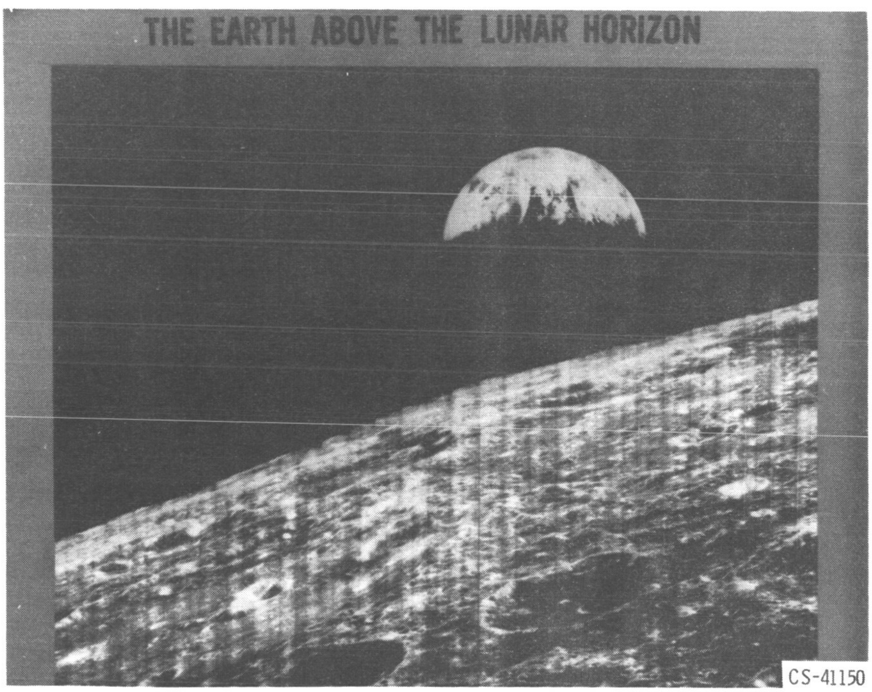
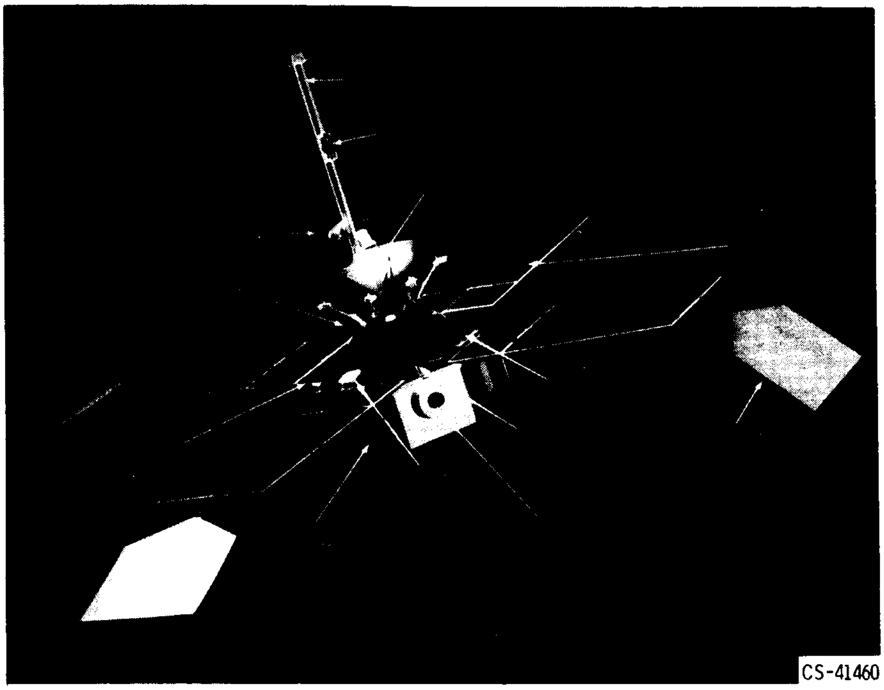
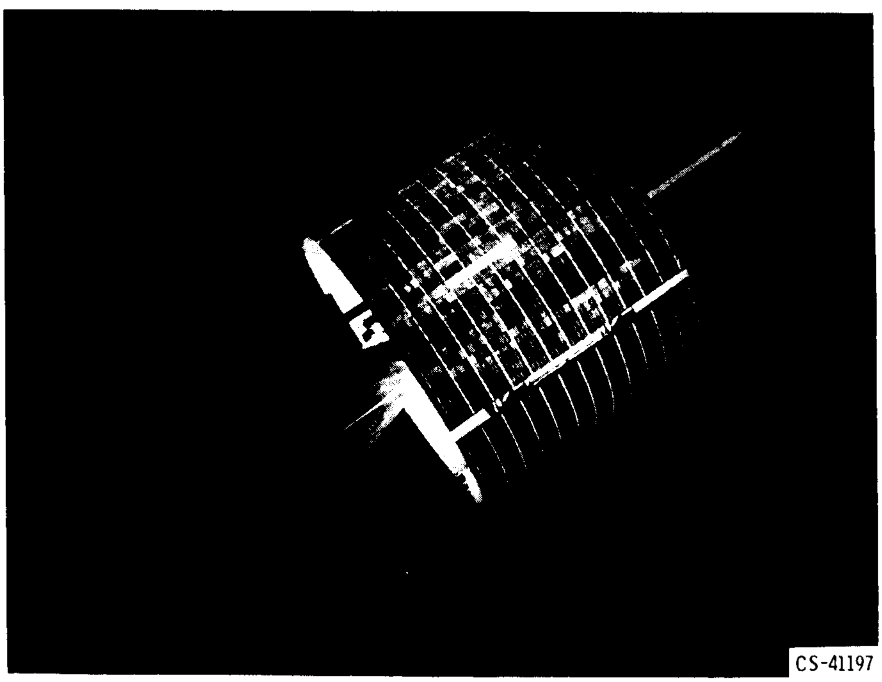


Figure 18. The view from 250,000 miles.



CS-41460

Figure 19. The Mariner-Mars spacecraft.



CS-41197

Figure 20. The Early Bird satellite - our first commercial venture in space.

E-3752

E-3732

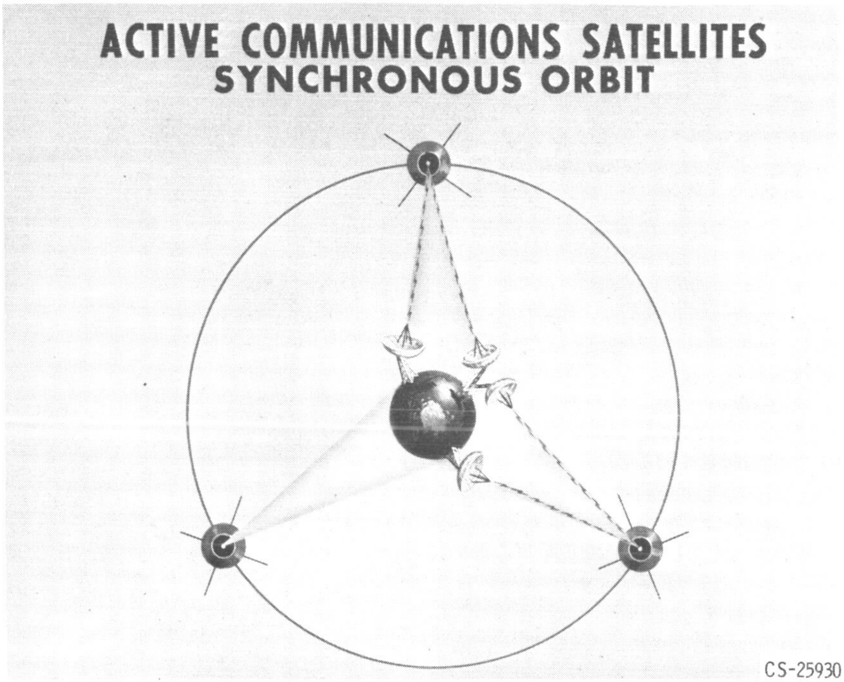


Figure 21. The global coverage of communications satellites.

Figure 22. A few of the scenes transmitted via Early Bird.

Figure 23. A town meeting of the world.

AVCS CAMERA COVERAGE

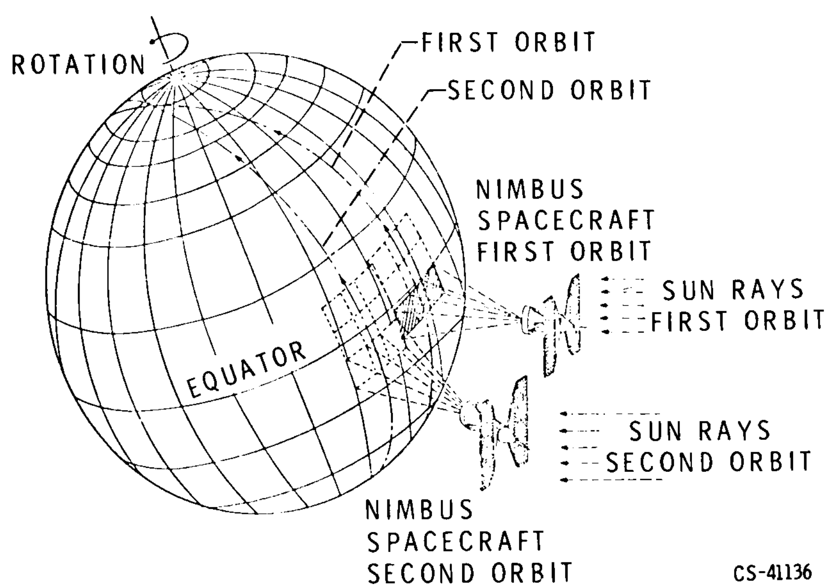


Figure 24. The global, continuous coverage of weather satellites.

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E-3732

HURRICANE ALMA OVER FLORIDA
PHOTO FROM NIMBUS II
JUNE 10, 1966

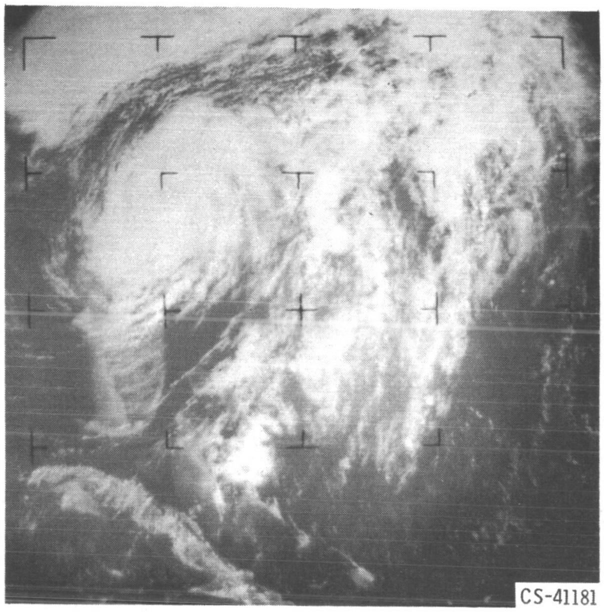

Figure 25. Hurricane Alma on the coast of Florida.

FIRST COMPLETE COVERAGE OVER NORTH AMERICA FROM ESSA I

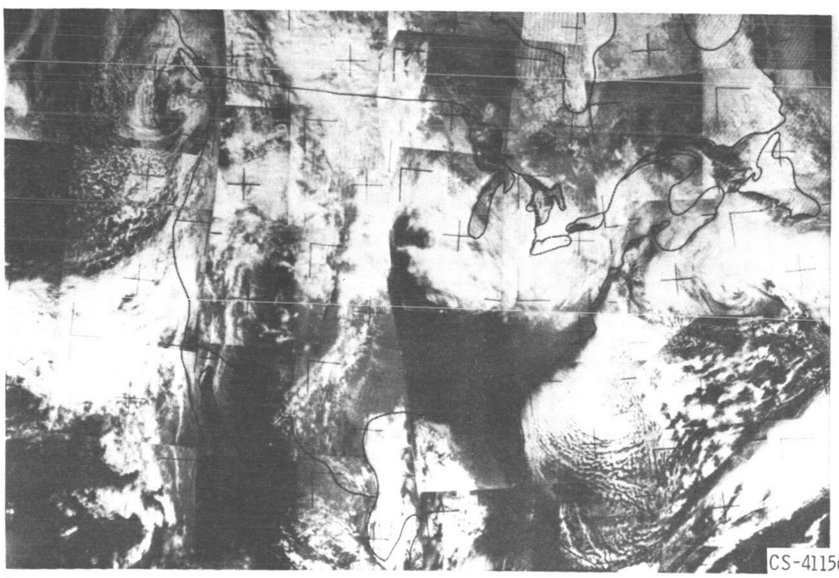

Figure 26. A mosaic showing the weather over the entire United States.

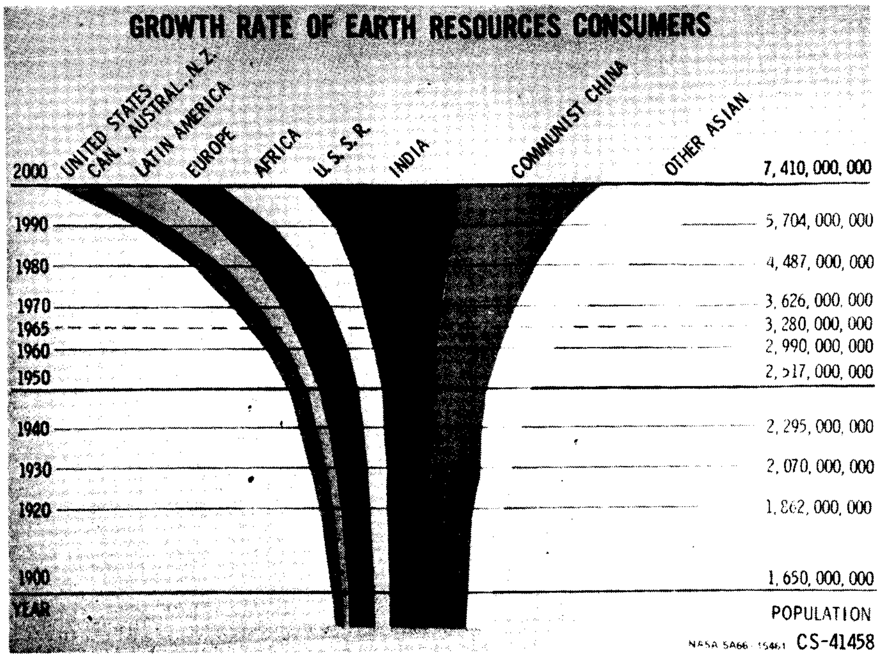

Figure 27. The anticipated growth of the world's population.

VIEW OF GREAT BAHAMA BANKS

NOTE DETAIL OF OCEAN BOTTOM INFORMATION. SMALL ISLANDS OF GREAT EXUMA, CAT AND LONG ARE ONLY LAND AREAS ALONG THE REEF

DEPTH OF WATER ON BANK IS ABOUT 30 FEET WHILE IN TONGUE OF THE OCEAN (IN LOWER LEFT) IT IS OVER ONE MILE DEEP

PHOTOGRAPHY TAKEN FROM GEMINI V ON 22 AUGUST 1965 ON THE 19TH ORBIT. ALTITUDE IS APPROXIMATELY 120 NAUTICAL MILES

CAMERA: HASSELBLAD, MODEL 500-C (NASA MODIFIED)

LENS: ZEISS PLANAR, 80 MM

FILM: KODAK, S O 217, (MS EKTACHROME), 70 MM WIDTH

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CS-41457

Figure 28. The Great Bahama Banks from Gemini.

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S  N

VIEW OF THE MOUTH OF THE COLORADO RIVER

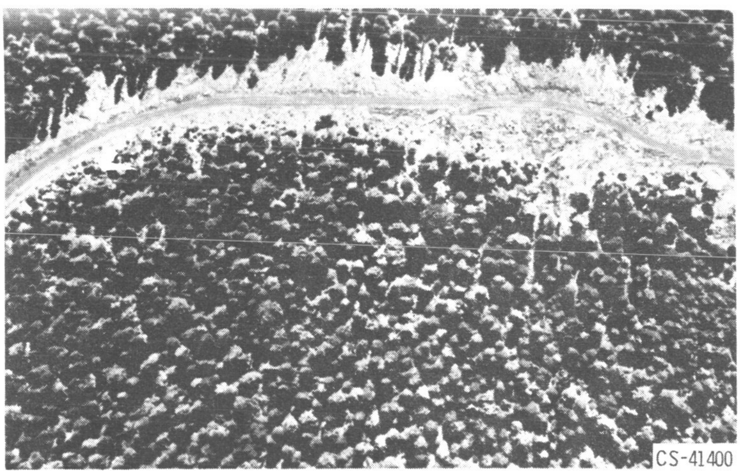
TAKEN FROM GEMINI 4 IN JUNE 1965 WITH A HASSELBLAD 500C ALTITUDE OF 110 120 N MI THE SONORA DESERT OF MEXICO OCCUPIES THE LOWER RIGHT HAND PART OF THE PHOTO

NASA SM65 15543
7 6 65

CS-41459

Figure 29. The mouth of the Colorado River.

USE OF AERIAL EKTACHROME INFRARED FILM
TO DETECT INSECT INFESTED TIMBER IN OREGON.
DAMAGED TREES APPEAR BLUE - GREEN
AND HEALTHY TREES APPEAR RED OR PINK



NASA ST66-15105 1-20-66

Figure 30. Measuring insect damage with airborne infrared sensors.